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ABSTRACT

This guide, part of a series of workplace-developed materials for retraining factory workers, provides teaching materials for a workplace mathematics course. The course is a review of basic number concepts focused on helping participants to understand the meaning of numbers and arithmetic operations. The introductory materials include a course outline, course objectives, a topical outline, information on course length and continuing education units, and resources. Lesson plans for four sessions are provided on the following topics: adding, subtracting, and multiplying decimals; using the metric system; calculating percents; interpreting control charts; and interpreting histograms. The session materials include objectives, topics, methods, evaluation criteria, a pretest and a posttest, information sheets, and handouts. (KC)

MERCER COUNTY
COMMUNITY
COLLEGE

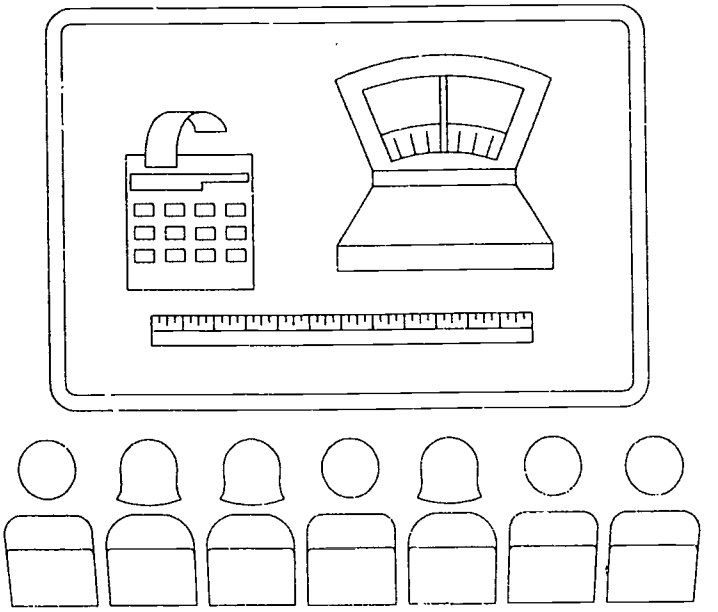
TRENTON • NEW JERSEY

Math Refresher/ Statistical Process Control

P.R.I.D.E.

PEOPLE RETRAINING for INDUSTRY EXCELLENCE

Math Refresher/SPC



Mercer County Community College

Division of Corporate and Community Programs

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Trenton, NJ 08690

Elaine S. Weinberg

Director, Workplace Skills

Developed with funds from the United States Department of Education

National Workplace Literacy Program

1995

ACKNOWLEDGMENT

Mercer County Community College thanks Jean Meier, Senior Education Specialist/Curriculum Developer for creating this manual. Through her valuable contributions employees in manufacturing and service industries learned concepts relevant to their existing jobs and strategies for learning other tasks if that opportunity should arise.

WORKPLACE SKILLS TRAINING PHILOSOPHY

A factory or service center creates a classroom that is very different from the one we are used to seeing in colleges and adult schools, so it only follows that our approach to teaching in the factory should also differ.

Our goal is to teach employees skills that they need in order to be functional and successful in their work environment, and encourage them to apply those skills on the job and at home. For example, we motivate students to do the following:

- work more efficiently and more safely
- make fewer mistakes
- solve problems working interactively
- take greater responsibility for their jobs
- recognize the interconnectedness of the various jobs in their workplace
- be better communicators in the workplace

Company needs are revealed through a needs assessment. At that time, we also determine the basic skills needs of the employees. We are learner centered, as the individual employee's needs are considered alongside those of the company.

Once we have determined those needs, we develop curricula that incorporate basic skills, using the workplace literature (e.g. forms, applications, codes, abbreviations, charts and tables, handbooks, regulations, procedures, policies, memos, letters) of the company. Because each company is different, the needs and literature are also different; hence, we develop new materials for every company in which we teach. By utilizing these workplace items, we help students transfer and apply their skills directly to their jobs.

We rely on the classroom techniques of problem solving, cooperative learning, and group discussion. Our overall approach is concept based, with the emphasis on application, such as in role plays, dialogues, and group work. Despite the specific course titles, we incorporate the elements of math, English, and communication skills into all of our sessions.

In terms of students evaluation, after initial testing we give a pre-test and post-test in order to determine comprehension. Students receive feedback throughout the course from the instructor, as well as from fellow students as we sincerely believe in the powerful positive reinforcement of peer critiques and cooperative exchanges.

In essence, we believe that although we make the materials for the students with which to work, it is the students who truly make the class.

MATH REFRESHER
STATISTICAL PROCESS CONTROL

COURSE OUTLINE:

This course is a review of basic number concepts focused on helping participants understand the meaning of numbers and arithmetic operations. Strategies are provided for increasing accuracy when doing computations with decimals and percents. Basic descriptive statistics will be covered including mean, median, mode, and standard deviation. Applications of these concepts to statistical process control will be emphasized including interpreting control charts and analyzing process capability.

OBJECTIVES:

Upon completion of this course, students will be able to:

- perform operations with decimals
- calculate per cents
- calculate mean, median, mode, and standard deviation
- draw histograms
- read and interpret control charts

TOPICAL OUTLINE:

- place value
- computations with decimals
- material variance
- per cent concepts
- normal curve
- histograms
- control charts

MATH REFRESHER
STATISTICAL PROCESS CONTROL

OTHER:

- Hours: 8
- CEU: 0.8

SOURCES:

The Transformation of American Industry, Developed for the Community College National Program.

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ SESSION 1

OBJECTIVES:

Upon completion of this session, students will be able to:

- add, subtract and multiply decimals
- use metrics

TOPICS:

- pretest
- arithmetic operations with decimals
- metric system
- decimal pounds

METHOD:

- lecture
- completion of pretest

EVALUATION:

- evaluation of pretest

MATERIALS:

- pretest
- handouts

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ PRETEST

1. There are 5 errors found out of 100 total checked. What is the error rate (%)?

_____

2. In the number 39.1852 what place is the 8 in?

   a. tenths b. hundredths c. thousandths d. ones

_____

3. Which is larger: 1.8 pounds or 1 pound 8 ounces?

_____

4. Find 1 % of 2200 lbs.

_____

5. Which is larger: 1 cc or 1 ml?

_____

6. What is half of .1?

_____

7. Put these numbers in order from smallest to largest:

0.1	1.58	.158	.3	0.05	.10
_____	_____	_____	_____	_____	_____

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ PRETEST

8. How many milliliters are in 1 liter?

_____

9. Find $\overline{X}$ and $\overline{\overline{X}}$ and R and $\overline{R}$ for the measurements given below:

TIME	1:00	2:00	3:00	4:00	5:00	6:00
	1.1	0.9	1.5	1.05	1.6	1.0
	2.2	2.1	2.1	2.0	2.4	2.9
	1.9	1.5	1.1	1.1	2.0	1.8
MEAN						
RANGE						

10. How many standard deviations (σ) above and below the mean are the upper and lower control limits (UCL and LCL) on a control chart?

_____

11. Name three things you would look for on a control chart that would tell you that the system is unstable or out of control.

_____ _____ _____

12. What is the major information you can learn from looking at a histogram of the data on a control chart?

_____

13. If the work order calls for .881 pounds of color additive and 16.735 pounds of virgin resin, what percentage of color is this?

_____

14. By mistake a run was completed at 4.5% color even though the work order called for 4% color. A total of 15,000 pounds of virgin resin was used. How much extra color additive was used over what the work order called for? How much did the extra cost at $5 per pound?

_____

_____

15. Write the following numbers:

- three tenths _____
- thirty thousandths _____

OPERATIONS WITH DECIMAL NUMBERS

A. Addition/Subtractions Skills
- add/subtract decimals, mixed decimals, and whole numbers
- add/subtract decimal fractions

Adding and Subtracting Decimal Fractions

To add/subtract decimal fractions:

1) arrange the numbers so that the decimal points are directly under each other,

2) add, as with whole numbers, and

3) place the decimal point in the answer directly under the other decimal points.

e.g. Add 5 + .02 Subtract 3.07 – .005

5.	3.070
+ .02	– .005
5.02	3.065

Note: To reduce the possibility of error, place zeros in all place values which have no digits.

OPERATIONS WITH DECIMAL NUMBERS

B. Multiplication and Division Skills
- multiply and divide decimals, mixed decimals, and whole numbers
- multiply and divide decimal fractions

Multiplying Decimal Numbers

To multiply decimals, multiply using the same procedure as with whole numbers. Place the decimal point in the answer the same number of decimal places as there are in both numbers being multiplied.

e.g.

	50.123	(3 places)
x	0.87	(2 places)
	43.60701	(5 places)

Dividing Decimal Numbers

To divide decimal fractions, (1) move the decimal point of the divisor as many places to the right as are necessary to make the divisor a whole number, (2) move the decimal point in the dividend the same number of places as were moved in the divisor, (3) place the decimal point in the quotient directly above the decimal point in the dividend, (4) add zeros to the dividend if necessary, and (5) divide as with whole numbers. Round as required.

e.g. Divide 0.643 by 0.28. Round to 3 decimal places

$$.28\overline{)0.6430} = 2.2964 \approx 2.296$$

COMMON/DECIMAL FRACTIONS

Express Common Fractions as Decimal Fractions

To express a common fraction as a decimal fraction requires division of the numerator by the denominator.

With repeating decimals, the division should be carried out one more place than the number of places required in the answer, then rounded.

Example: express $\frac{5}{7}$ as a 2 place decimal

$$\frac{5}{7} = 5 \div 7 = 7\overline{)5.000}^{.714} = .71$$

Express Decimal Fractions as Common Fractions

Read the place value of the last digit.

Example:

$$0.357 = \frac{357}{1000}$$

DECIMAL FRACTIONS

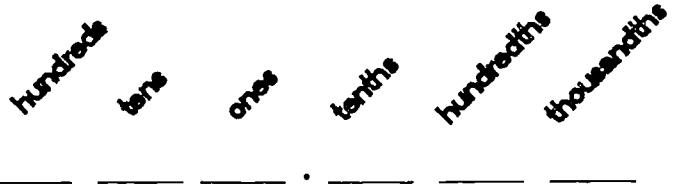
To read a decimal fraction, read the number as a whole number, then say the name of the place value where the last digit falls.

The following three numbers all have the same value:

0.5 is read as 5 tenths

0.50 is read as 50 hundredths

0.500 is read as 500 thousandths



The value of a number is determined by its place or location compared to the *decimal point*. A number has many different values depending on which place it is in.

Circle the largest number in each pair:

.1	.01
.6	.60
.6	.09

The decimal point is usually not written in whole numbers but it can be put in.

⇒ Where is the decimal point understood to be in the number 592?

⇒ What is half of .1?

⇒ What is twice as big as .8?

⇒ How much money would .8 represent?

MULTIPLICATION TIPS

☐ .25 means **one quarter** therefore

multiplying by .25 is the same as ***dividing by 4***

Example: .25 X 80 = 20

⇔ or ⇔

80 ÷ 4 = 20

☐ .5 means **one half** therefore

multiplying by .5 is the same as ***dividing by 2***

Example: .5 X 62 = 31

⇔ or ⇔

62 ÷ 2 = 31

☐ .1 means **one tenth** therefore

multiplying by .1 is the same as ***dividing by 10***

Example: .1 X 8.7 = .87

⇔ or ⇔

8.7 ÷ 10 = .87

☐ .01 means **one hundredth** therefore

multiplying by .01 is the same as ***dividing by 100***

Example: .01 X 946 = 9.46

⇔ or ⇔

946 ÷ 100 = 9.46

CALCULATOR

To erase the display when you begin a new problem or to erase a keying error –

C	Clear
CE	Clear Entry

To Clear the Memory

AC	All Clear
CM	Clear Memory
MC	Memory Clear
M^{R}_{C}	Recall Memory (press the key once) Clear Memory (press the key twice)

Memory Keys

M+	Add to the Memory
M–	Subtract from the Memory
RM	Recall Memory

CALCULATOR

Examples:

To get a final total –

- ▲ Add each subtotal to the memory
- ▼ Recall the memory to get the final total

7 X 8 [M+]

9 X 10 [M+]

[RM]

Repetitive arithmetic: Use the operation key twice

▲ To multiply many numbers by 567:

567 [X] [X] 9 [=]

12 [=]

13 [=]

▲ To subtract 50 from many numbers:

50 [−] [−] 287 [=]

175 [=]

350 [=]

▲ If you need a total after doing repetitive multiplication, use the operation key twice then [M+]

567 [X] [X] 9 [M+]

12 [M+]

13 [M+]

[RM]

AUTOMATED PRODUCTION SYSTEMS TO METRIC OR ENGLISH STANDARDS

LINEAR

1 inch	=	2.54 cm	=	25.4 mm
1 foot	=	.3048 meter		
1 yard	=	.9144 meter		
1 mile	=	1.609 kilometer		
1 micron	=	.001 mm	=	.000039 inch
1 mm	=	.03937 inch		
1 cm	=	.3937 inch		
1 meter	=	39.37 inches		
1 kilometer	=	.6214 mile		

CUBIC

1 cc	=	.061 cubic inch		
1 liter	=	1000 cc	=	61.023 cubic inches
1 liter	=	1.0567 U.S. quart		
	=	.2642 U.S. gallon		
1 liter	=	.8799 Imperial quart		
	=	.2200 Imperial gallon		
1 cubic meter	=	1.308 cubic yard		
	=	264.2 U.S. gallons		

WEIGHT

1 metric ton	=	.9842 ton (of 2240 lbs)
	=	2204.6 lbs
1 metric ton	=	1000 kilograms
1 kilogram	=	2.2046 lbs
	=	35.274 oz avoirdupois
1 gram	=	.03527 oz avoirdupois
	=	15.432 grains

AUTOMATED PRODUCTION SYSTEMS TO METRIC OR ENGLISH STANDARDS (CON'T)

OTHER

1 kilogram/mm^2	=	1422.32 lbs/in^2
1 kilogram/mm^2	=	14.223 lbs/in^2
1 kilogram/meter	=	7.233 ft-lbs
1 lb/in^2	=	.0703 kilogram/cm^2
1 kilogram calorie	=	3.968 B.T.U.

Note:
cm	=	centimeter
mm	=	millimeter
cc	=	cubic centimeter

METRICS

In the metric system the root word used indicates what is being measured:

- **Liters** are used to measure **liquid volume**
- **Grams** are used to measure **weight**
- **Meters** are used to measure **distance**

The same prefixes are used with each root word:

Kilo	Hecto	Deka	**Unit**	Deci	Cent	**Milli**
			Liter			
			Gram			
			Meter			

Measurements get 10 times larger each place you go to the left

☞ *or*

10 times smaller each place that you move to the right.

☞ *therefore*

You can convert from one unit to the other by simply moving the decimal point one place left or right for the number of places you move left or right on the chart

1. Is a milliliter (ml.) larger or smaller than a liter (L.)? By how much?

2. For instance 5L. would be _____ ml. (move the decimal point 3 places to the left)

3. Try the following:

81 L.	=	ml.		67 ml.	=	L.
7 L.	=	ml.		.475 L	=	ml.

4. In the metric system one cubic centimeter (1 cc.) = 1 ml.

Therefore:	59 ml.	=	cc.		6 L.	=	cc.

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ SESSION 2

OBJECTIVES:

Upon completion of this session, students will be able to:

- calculate percents

TOPICS:

- changing fractions to decimals to percents
- finding a percent of a number
- problem solving with percents

METHOD:

- lecture
- completion of handouts

EVALUATION:

- self evaluation

MATERIALS:

- handouts
- workorders
  (use individual company's specific workorders for reference)

PERCENTS

Percent means ***per hundred out of a hundred*** or ***divided by a hundred***

therefore

5% can be written $\frac{5}{100}$ or 5 ÷ 100 or .05

To find a percent of a number:
1. Change the percent to a decimal 2. Multiply

Example: Find 3% of 10.4

1. Change 3% to .03
2. Multiply .03 X 10.4

   = .312

To find what percent one number is of another number:
1. Divide (Part ÷ Whole) 2. Change to a percent

Example: What percent is 3 out of a total of 400?

1. Divide 3 ÷ 400 = .0075
2. Change to a percent .0075 = .75%

PER CENTS

Find the missing percent, decimal, or fraction.

	Percent	Decimal	Fraction
1.		.25	
2.			$\frac{1}{40}$
3.	300%		
4.	.5%		
5.		.012	
6.		.15	
7.		.2	
8.	80%		
9.			$\frac{3}{4}$
10.			$\frac{70}{100}$

11. 67 is 4% of what number? _____

12 What is 15% of 86? _____

13. 92 is what percent of 98? _____

PER CENTS EXERCISES – I

1. Calculate the percent increase or decrease in each case:

   - $5,000 increased to $8,000

     _____

   - $45,200 decreased to $45,000

     _____

   - this year it cost $560 but last year it was only $540

     _____

   - this year it cost $7,890 after the price was increased $100

     _____

2. It is predicted that inflation will be 3% this year. Find the cost of an item for each year indicated:

Current Price (3/94)	Year	Projected Price
$900	9/94	
$900	1995	
$900	1996	
$900	1997	
$900	1998	
$900	1999	
$900	2000	

PER CENTS EXERCISES – 1 (CON'T)

3. Now calculate simple interest on the same item.

Simple Interest = P X R X T

Current Price (3/94)	Year	Simple Interest
$900	9/94	
$900	1995	
$900	1996	
$900	1997	
$900	1998	
$900	1999	
$900	2000	

4. The price this year was $1,000. This is a 5% increase over last year. How much did it cost last year?

_____

PER CENTS EXERCISES – II

1. Sales tax is 6%. If you buy an item for $1,500 how much would you pay in taxes?

_____

2. There are 6 errors found out of 193 items checked. What is the error rate (%)?

_____

3. Last year they deducted $17.19 from your paycheck every week for medical coverage. The rates went up 10%. How much will they deduct this year?

_____

4. If $107.10 was paid in taxes and the tax rate was 6%, what was the cost of the product?

_____

5. There are now 800 people working for the company. If ten years ago there were only 600, what is the percent of increase?

_____

6. Your salary of $19,000 will soon increase by 8.5%. How many dollars will your salary increase? How much more money will you see on each weekly paycheck?

_____

PER CENTS EXERCISES – II (CON'T)

7. A person worked on a job for 5 hours but only completed 40% of the job. How many more hours are needed to finish the job?

_____

8. A tax of $6.75 on a purchase of $125 represents what tax rate?

_____

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ SESSION 3

OBJECTIVES:

Upon completion of this session, students will be able to:

- interpret control charts
  (use individual company's specific charts for reference)

TOPICS:

- overview of SPC
- mean, median, mode, and standard deviation
- normal curve
- completing control charts
- calculating LCL and UCL
- interpreting control charts
- attribute charts

METHODS:

- lecture
- completion of handouts

EVALUATION:

- self evaluation

MATERIALS:

- control charts

Filling Level Data

Product Code	Date	
Product	CF #	
NJ # Batch OK by	Machine #	Quantity
	Correct Tube and Label	OK to start run by

_____ (Specific Gravity) x _____ (Theoretical Volume) = _____ Calculated Weight

\+

_____ + _____ + _____ = _____ ÷ 3 = _____ Tare Weight
(Empty Tube Weights) (Total)

=

_____ **Minimum Fill Weight**

Specifications: _____ (Minimum Fill Weight) x 1.05 = _____ **Maximum Fill Weight**

Time																
Test + Test + Test =	1															
	2															
	3															
Total																
Average (total ÷ 3)																
Range																

$\overline{X}$

R

BODY OVALITY

File: cyc10008
Single-sided Specification Conversion Sheet

GIVEN:

R-BAR	=	Average of all ranges
X-BAR	=	Average of all measurements in a set
X-DOUBLE BAR	=	Average of all X-BARS
N	=	Number of bottles in a set
$\mathbf{d^2}$	=	Conversion factor used based on what "N" equals

Example:

- If **N** = 3, $\mathbf{d^2}$ = 1.69
- If **N** = 7, $\mathbf{d^2}$ = 2.70
- If **N** = 12, $\mathbf{d^2}$ = 3.26

PCI = Process Capability Indices

⌘ There are 5 capabiiity indices but we are only concerned with the "Upper Process Performance CPU" in dealing with a one-sided spec.

FORMULAS:

$$\text{SIGMA} = \frac{\text{R - BAR}}{\text{N}} \qquad \text{CPU} = \frac{\text{USL} - \text{X - DOUBLE BAR}}{3 \times \text{SIGMA}}$$

WORKSHEET: $\frac{50}{60}$ cc / 8.5 sec cycle / .015 USL

$$\text{SIGMA} = \frac{0.0209}{3.26} = 0.0064$$

$$\text{CPU} = \frac{-0.003}{0.01923} = -0.155$$

If CPU is < 1.0 then process is not capable.

Note: Formulas from "Defect Prevention; Use of Simple Statistical Tools"

WHAT IS SPC?

■ STATISTICAL

- With the help of numbers

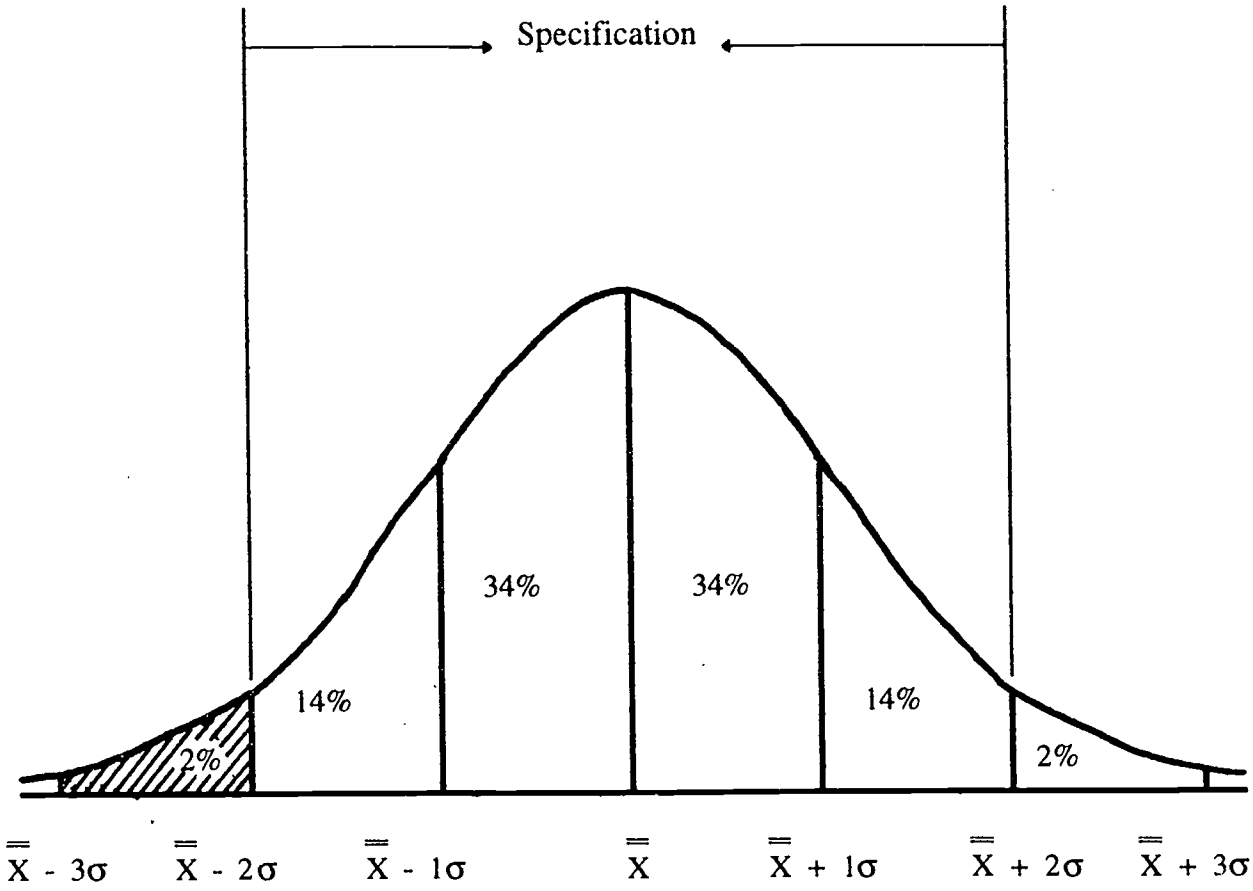
■ PROCESS

- We study and analyze an operation or service

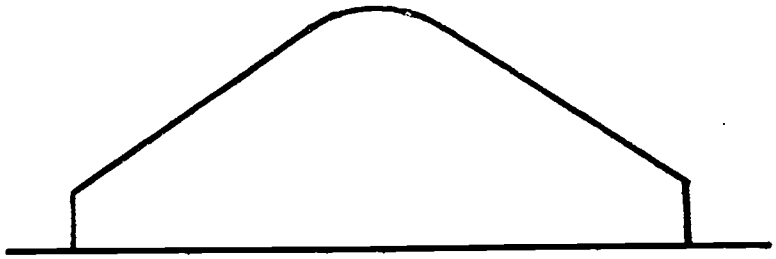
■ CONTROL

- To produce what the customer requires

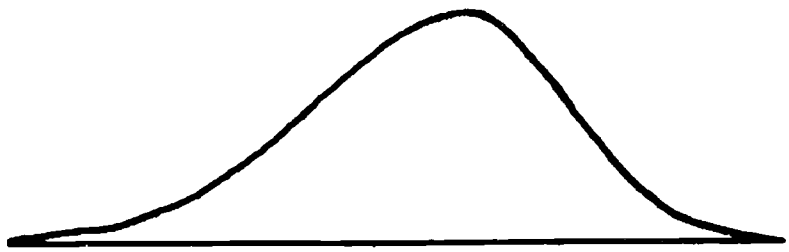
APPROXIMATE PERCENTAGES IN A NORMAL DISTRIBUTION CURVE



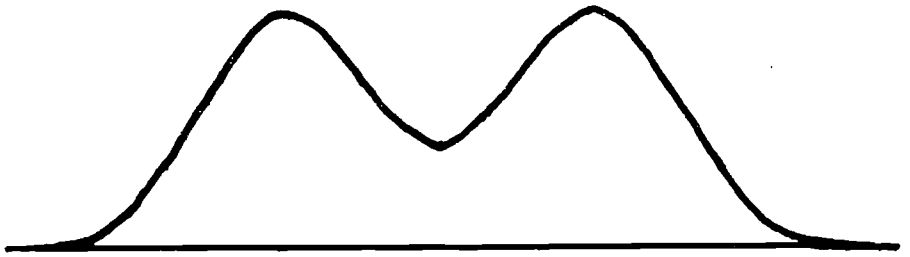
TAILS OF THE DISTRIBUTION "CHOPPED OFF": ITEMS WERE PROBABLY SORTED.



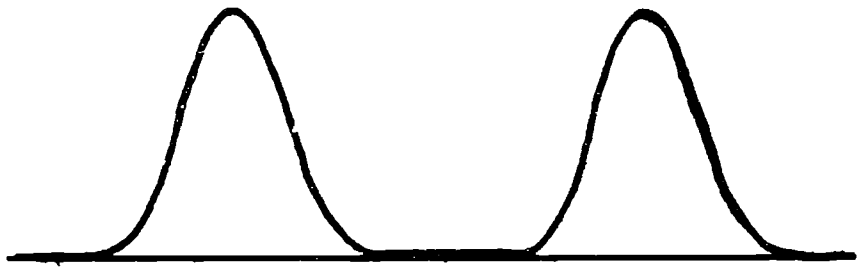
MEASUREMENTS TAIL OFF TO LEFT



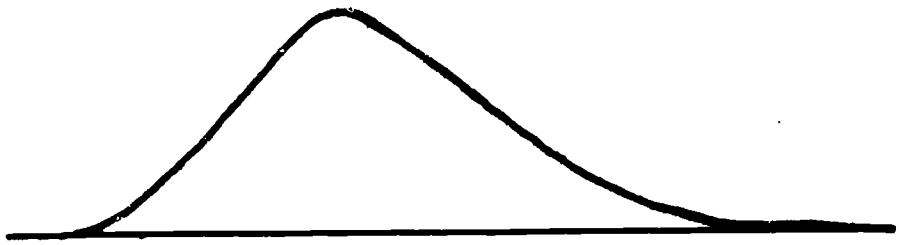
MEASUREMENTS FROM TWO DIFFERENT GROUPS THAT OVERLAP



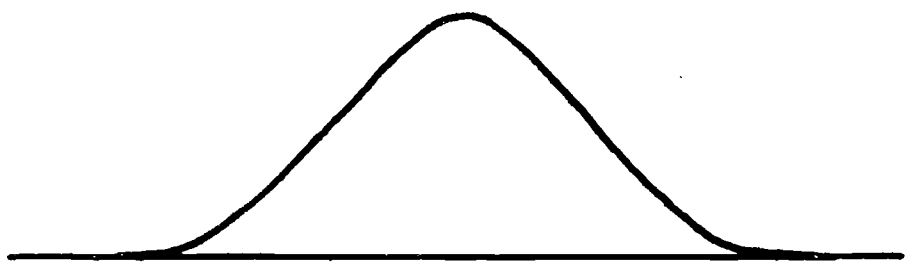
MEASUREMENTS FROM TWO DIFFERENT GROUPS



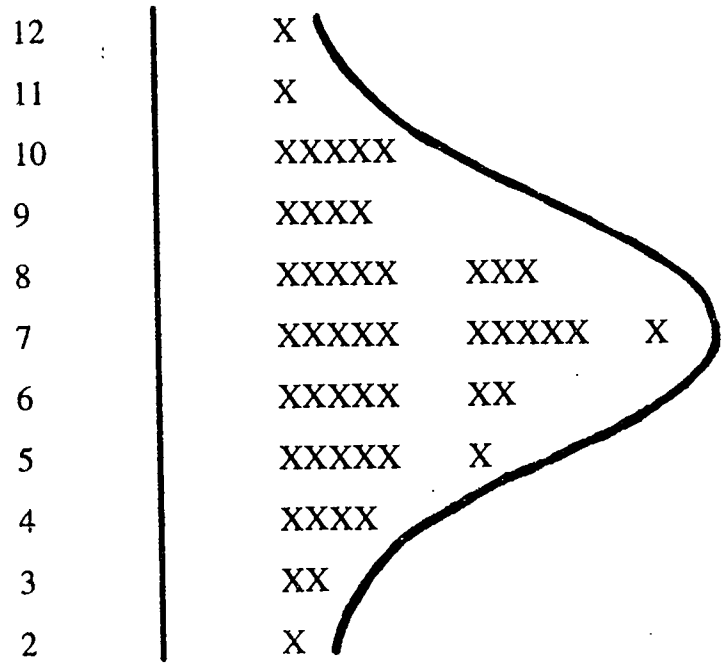
MEASUREMENT TAILS OFF TO RIGHT



NORMAL DISTRIBUTION



BELL-SHAPED CURVE



BASIC PRINCIPLES

- No two things are exactly alike
- Variation in a product or process can be measured
- Things vary according to a definite pattern
- Whenever things of the same kind are measured, a large group of the measurements will tend to cluster around the middle
- It's possible to determine the shape of the distribution curve for parts produced by any process
- Variation due to assignable causes tend to distort the normal distribution curve

p CHARTS: KEY POINTS OF USE

- Subgroup greater than 50
- Average number of defects or defectives is equal to or greater than 4
- If sub group size is +/- 50% of the average sub group size, the data point must be discarded or the control limits recalculated for each sub group
- p charts are not always suitable: when sample values are too large the control limits will be tight and most points will fall outside
- p charts are the second most sensitive statistical chart. The most sensitive and expensive is the X-bar and R chart

TYPES OF ATTRIBUTE CHARTS

Chart	Records	Subgroup Size
p	Percent/fraction of non-conformings	Varies
np	Number of non-conformings	Constant
c	Number of non-conformities	Constant
u	Number of non-conformities per unit	Varies

USES FOR ATTRIBUTE CHARTS

- Follow trends and cycles

- Evaluate any change (variable) in a process:

  * Did it reduce defects, increase defects, or have no effect on defects? *

Attribute Charts

- An attribute is defined as an "inherent characteristic"

  Examples:

  - ◊ Short or Tall
  - ◊ Fat or Thin
  - ◊ Red or Yellow
  - ◊ Good or Bad
  - ◊ Pass or Fail

INTERPRETATION OF CONTROL CHARTS

SPECIALS OBSERVATIONS ABOVE OR BELOW THE UCL OR LCL'S

- *Run*
  - Seven consecutive points above or below the centerline

- *1-in-20*
  - More or less than 1-in-20 observations close to the UCL or LCL [outer third]

- *Trend*
  - Five points either upward or downward towards the UCL or LCL

CALCULATION WORKSHEET

Control Limits

n = _____ $\bar{X}$ = _____ $\bar{R}$ = _____

$\bar{X}$ $UCL_{\bar{X}} = \bar{X} + A_2\bar{R}$

$UCL_{\bar{X}}$ = _____ + (_____ x _____)

$UCL_{\bar{X}}$ = _____ + (_____)

$UCL_{\bar{X}}$ = _____

$LCL_{\bar{X}} = \bar{X} - A_2\bar{R}$

$LCL_{\bar{X}}$ = _____ - (_____)

$LCL_{\bar{X}}$ = _____

R $UCL_R = D_4\bar{R}$

UCL_R = _____ x _____

UCL_R = _____

LCL_R = 0

Process Capability

USL = _____ LSL = _____

$Cp = \frac{d_2(USL - LSL)}{6 \times \bar{R}}$

$Cp = \frac{\_\_\_\_\_(\_\_\_\_\_ - \_\_\_\_\_)}{6 \times \_\_\_\_\_}$

Cp = _____

$Cpu = \frac{d_2(USL - \bar{X})}{\bar{R}}$ $CpL = \frac{d_2(\bar{X} - LSL)}{\bar{R}}$

Cpu = _____ CpL = _____

Z min = Lower of Cpu and CpL

$Cpk = \frac{Z\ min}{3}$ = _____ + 3 = _____

FACTORS

n	A_2	D_4	d_2
2	1.88	3.27	1.13
3	1.02	2.57	1.69
4	.73	2.28	2.06
5	.58	2.11	2.33
6	.48	2.00	2.53

Rules for Interpreting Control Charts

1. Are there any points above the upper control limit or below the lower control limit?
2. Are there 7 points in a row above or below the center line?
3. Is there more than 1 point in twenty consecutive points close to the control limits (outer one-third)?
4. Are there any upward or downward trends of 5 consecutive points or drifts of 7 or more points?

GLOSSARY OF TERMS X-BAR AND R CHARTS

- n
  - Sample size
- X
  - Data [a single reading]
- $\overline{X}$
  - Average of readings in a sample
- $\overline{\overline{X}}$
  - Average of all the X-bars: value of the center line of the X-bar chart
- R
  - Range: the difference between the largest/smallest value in a sample
- $\overline{R}$
  - Average of all the R's: value of the center line of the R chart
- UCL
  - Upper control limit: the upper boundary for 99.73% of the population
- LCL
  - Lower control limit: the lower boundary for 99.73% of the population

STEPS FOR CONSTRUCTING X-BAR & R CHARTS

#	ACTIVITY
1.	Determine the sample size (n = 3, 4, or 5) and the frequency of sampling
2.	Collect 20-25 sets of time sequenced samples There should be at least 80-100 individual data points
3.	Calculate the averages of each set of n = 3, 4, or 5 Samples (= X-bar)
4.	Calculate the range for each set of n = 3, 4, or 5 Samples (= R)
5.	Calculate $\bar{\bar{X}}$ (the average of all the X-bar's) This is the center line of the X-bar chart
6.	Calculate the R-bar (the average of all the R's) This is the center line of the R chart
7.	Calculate the upper and lower control limits
8.	Plot the data on chart paper Interpret the chart for special and assignable causes

p Chart	np Chart	c Chart	u Chart
$p = \frac{np}{n}$ for fraction $p = \frac{np}{n} \times 100$ for percentage $UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\bar{n}}}$ $LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\bar{n}}}$ $\bar{n} = \frac{\sum n}{k}$ $\bar{p} = \frac{\sum np}{\sum n}$	$n\bar{p} = \frac{\sum np}{k}$ $UCL_{np} = n\bar{p} + 3\sqrt{n\bar{p}(1-\frac{n\bar{p}}{n})}$ $LCL_{np} = n\bar{p} - 3\sqrt{n\bar{p}(1-\frac{n\bar{p}}{n})}$	$\bar{c} = \frac{\sum c}{k}$ $UCL_c = \bar{c} + 3\sqrt{\bar{c}}$ $LCL_c = \bar{c} - 3\sqrt{\bar{c}}$	$u = \frac{c}{n}$ $UCL_u = \bar{u} + 3\frac{\sqrt{\bar{u}}}{\sqrt{\bar{n}}}$ $LCL_u = \bar{u} - 3\frac{\sqrt{\bar{u}}}{\sqrt{\bar{n}}}$ $\bar{n} = \frac{\sum n}{k}$ $\bar{u} = \frac{\sum c}{\sum n}$
Attribute:	Defectives	Defectives	Defects	Defects
Sample size:	Varies	Fixed	Fixed	Varies
Charted as:	% Defective Units	No. of Defectives	No. of Defects	Average no. of defects per unit

Calculations:

Rules for interpreting control charts

1. Are there any points above the upper control limit or below the lower control limit?
2. Are there 7 points in a row above or below the center line?
3. Is there more than 1 point in twenty consecutive points close to the control limits (outer one-third)?
4. Are there any upward or downward trends of 5 consecutive points or drifts of 7 or more points?

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ SESSION 4

OBJECTIVES:

Upon completion of this session, students will be able to:

- interpret histograms
  (use individual company's specific histograms for reference)

TOPICS:

- kurtosis
- skewness
- chi squared
- Cp, Cpk, Cr
- posttest

METHOD:

- lecture
- completion of posttest

EVALUATION:

- evaluation of posttest

MATERIALS:

- posttest
- histograms
- handouts

STEPS IN CONSTRUCTING HISTOGRAMS

Step 1 Collect the measurements

Step 2 Find and mark the smallest and largest number in each group

Step 3 Find and mark the smallest and largest number in the whole set

Step 4 Calculate the range

Step 5 Determine intervals, boundaries, and midpoints

Step 6 Determine frequencies

Step 7 Prepare histogram

STEPS IN CONSTRUCTING HISTOGRAMS

Step 1:

- Collect measurements

Step 2:

- Find smallest and greatest number in each group

Step 3:

- Find the smallest and greatest number in each set

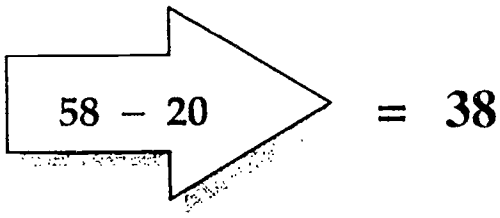
.032	.044	.044	.042	.057
.026	.051	.023	.033	.027
.042	.046	.043	.045	.044
.053	.037	.025	.038	.044
.036	.040	.036	.048	.055
.047	.040	.058	.045	.038
.032	.039	.043	.031	.045
.041	.037	.031	.039	.033
.020	.050	.033	.050	.051
.028	.051	.040	.052	.043

STEPS IN CONSTRUCTING HISTOGRAMS

Step 4:

- Calculate the "range" of the measurements

  ⇨ Subtract the smallest number from the largest number



  ⇨ Consult table to ID number of "intervals"

  - Too few intervals "hide" information that might have value
  - Too many intervals "flatten" the picture
  - Guidelines for determining the numbers of all

Number of Readings	*Number of Intervals*
Fewer than 50	5 to 7
50 – 100	6 to 10
101 – 150	7 to 12
More than 150	10 to 12

STEPS IN CONSTRUCTING HISTOGRAMS

Step 5:

- Determine interval, boundaries, and midpoint

  ⇨ *Interval:*

  - Divide the range of the data by the intervals

    38/8 = 4.75

  - Round Off

    4.74 to 5 .0

  - Use 5 as the interval

  ⇨ ***Boundaries:***

  - Every reading must fall between two boundaries
  - The first boundary is 20 [the smallest number]
  - Describe the "bins" as [20-24], [25-29], [30-34]...

  ⇨ ***Midpoint:***

  - Set the mid-point at the center of the interval
  - It is OK to round off or round up

STEPS IN CONSTRUCTING HISTOGRAMS

Step 6:

- Tally the frequencies

Midpoint	*Interval*	*Boundaries*	*Tally*	*Frequency*
			TOTAL	

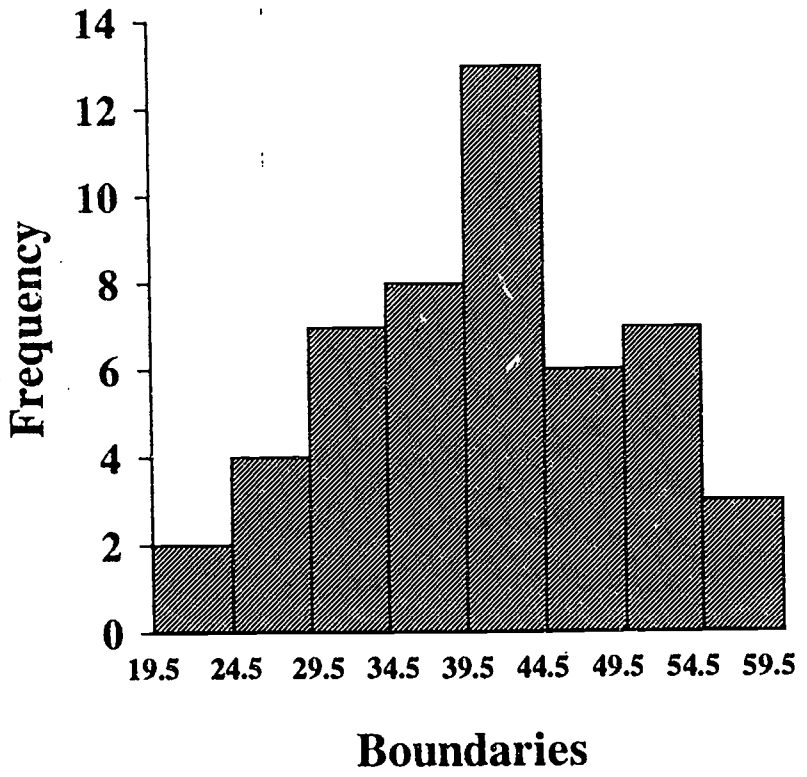
Step 7:

- Draw the frequency histogram

1. Label [title] the frequency histogram
2. Mark and label the vertical scale
3. Mark and label the horizontal scale
4. Draw "bars" according to the tally
5. [Kiss] Keep it smart and simple
6. "Just the facts, Madam!"

Sgt. Joe Friday
Dragnet 1956

HISTOGRAM


14
12
10
8
6
4
2
0
Frequency
19.5
24.5
29.5
34.5
39.5
44.5
49.5
54.5
59.5
Boundaries

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ POSTTEST

1. There are 5 errors found out of 100 total checked. What is the error rate (%)?

_____

2. In the number 39.1852 what place is the 8 in?

   a. tenths b. hundredths c. thousandths d. ones

_____

3. Which is larger: 1.8 pounds or 1 pound 8 ounces?

_____

4. Write $1\frac{3}{4}$ as a decimal.

_____

5. Find 1 % of 2200 kg.

_____

6. Which is closest to .5 gallons?

   a. .2 L b. 2 L c. 20 L d. 200 L

_____

7. True or False: 16 ÷ .5 = 32

_____

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ POSTTEST

8. The ratio of 1.8 to 2 is the closest to which of the following:

9 to 1	9 to 10	9 to 200	18 to 100	1 to 10

_____

9. Which is larger: 1 cc or 1 ml?

_____

10. Put these numbers in order from smallest to largest:

0.1	1.58	.158	.3	0.05	.10
_____	_____	_____	_____	_____	_____

11. How many milliliters are in 1 liter?

_____

12. How many grams are there in 5 kilograms?

_____

13. What is half of .1?

_____

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ POSTTEST

14. Find the overall mean, median, mode, and range for the measurements given below:

	1.1	0.9	1.5	1.05	1.6	1.0
	2.2	2.1	2.1	2.0	2.4	2.9
	1.9	1.5	1.1	1.1	2.0	1.8
MEAN						
MEDIAN						
MODE						
RANGE						

15. How many standard deviations (σ) above and below the mean are the upper and lower control limits (UCL and LCL) on a control chart?

_____

16. What is the difference between a process that is in control and a capable process?

_____

_____

17. What is the major information you can learn from looking at a histogram of the data on a control chart? Why is it important?

_____

_____

_____

MATH REFRESHER
STATISTICAL PROCESS CONTROL ♦ POSTTEST

18. If the work order calls for .881 pounds of color additive and 16.735 pounds of virgin resin, what percentage of color is this?

_____

19. By mistake a run was completed at 4.5% color even though the work order called for 4% color. A total of 15,000 pounds of virgin resin was used. How much extra color additive was used over what the work order called for?

_____

_____

20. Write the following numbers:

- three tenths _____
- thirty thousandths _____

21. Round each of the following numbers to the indicated number of decimal places.

- 0.6666666666 [to hundredths] _____
- 0.80729 [to thousandths] _____